Video Article

The Deese-Roediger-McDermott (DRM) Task: A Simple Cognitive Paradigm to Investigate False Memories in the Laboratory

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Abstract

The Deese, Roediger and McDermott (DRM) task is a false memory paradigm in which subjects are presented with lists of semantically related words (*e.g.*, nurse, hospital, *etc.*) at encoding. After a delay, subjects are asked to recall or recognize these words. In the recognition memory version of the task, subjects are asked whether they remember previously presented words, as well as related (but never presented) critical lure words ('doctor'). Typically, the critical word is recognized with high probability and confidence. This false memory effect has been robustly demonstrated across short (*e.g.*, immediate, 20 min) and long (*e.g.*, 1, 7, 60 d) delays between encoding and memory testing. A strength of using this task to study false memory is its simplicity and short duration. If encoding and retrieval components of the task occur in the same session, the entire task can take as little as 2 - 30 min. However, although the DRM task is widely considered a 'false memory' paradigm, some researchers consider DRM illusions to be based on the activation of semantic memory networks in the brain, and argue that such semantic gist-based false memory errors may actually be useful in some scenarios (*e.g.*, remembering the forest for the trees; remembering that a word list was about "doctors", even though the actual word "doctor" was never presented for study). Remembering the gist of experience (instead of or along with individual details) is arguably an adaptive process and this task has provided a great deal of knowledge about the constructive, adaptive nature of memory. Therefore, researchers should use caution when discussing the overall reach and implications of their experiments when using this task to study 'false memory', as DRM memory errors may not adequately reflect false memories in the real world, such as false memory in eyewitness testimony, or false memories of sexual abuse.

Video Link

The video component of this article can be found at https://www.jove.com/video/54793/

Introduction

The Deese, Roediger and McDermott (DRM) task was initially created by Deese[1], and later revitalized by Roediger and McDermott[2] as a convenient means of studying false memory in the laboratory. Although some[3,4] argue it should be called the DRMRS task, for the contributions of Read[5] and Solso[6], the most common name in the literature is the DRM task, and we call it by that name here. After a seminal paper published by Roediger and McDermott[2], interest of false memory research skyrocketed (see[7]), resulting in over 2,800 citations of that article to date. According to Roediger and McDermott, they revived the experimental design created by Deese because there was no reliable laboratory paradigm to induce false recall, while evidence of false recognition (e.g.,[8,9]) did "little to discourage the belief that more natural, coherent materials are needed to demonstrate powerful false memory effects"[2].

One such example of a "more natural" paradigm is the misinformation paradigm[10,11]. In this task, subjects are presented with a story through pictures, slides, or video. Later, misleading information is provided, and the question is whether subjects will incorporate this misleading information into their recollection of the story. The DRM task is simpler than the misinformation paradigm in several respects. DRM encoding requires only the quick presentation and learning of lists of words, either visually or aurally. Retrieval testing for the DRM task is equally convenient regardless of the particular method used. In a recognition test participants are presented with a subset of the encoded words, the critical lure words (*e.g.*, 'doctor'), and unrelated lure words and have to make simple judgments of whether they remember each word or not, whereas in a recall test, participants have to write down all the words they are able to remember. In contrast, free recall testing for the misinformation paradigm is impractical, as it requires time-consuming content analysis. Additionally, the DRM task does not require any manipulation between encoding and testing, as DRM 'false memories' are spontaneously self-generated. The misinformation errors, on the other hand, are induced via external suggestions. Although both the DRM and misinformation paradigms are argued to assess false memory, newer studies have found small ($r = 0.12$)[12] or no relationship[13,14] between the misinformation and the DRM effects, suggesting that different mechanisms may be at play for each type of false memory. Moreover, the DRM illusions are argued to be a byproduct of the constructive nature of memory[15], which can be considered an evolutionarily adaptive process[16].

The DRM false memory effect is highly robust across studies (for quantitative reviews see [17,18]), and there is considerable evidence that the DRM task is quite reliable[19] (but see[20]). The DRM false memory effect has been found using various delay intervals, including those as short as an immediate test, and those delaying memory testing until 60 days later[21,22,23] (but see [24]). Warning subjects of the DRM illusion reduces, but does not erase, the effect [14,25]. The DRM effect has also been found with different encoding strategies, such as changes in word presentation duration[26], and can be increased by several post-encoding manipulations, such as sleep[27] or stress[28].

Moreover, the DRM task has been utilized by many laboratories to study false memory formation in a variety of subject populations, such as children[29,30,31,32] and older adults[33], and in a variety of research fields, including individual cognitive (*e.g.*, working memory[20,34]) and personality differences[35], neuroimaging[36,37], and neuropsychology[38]. In spite of its popularity, however, many have argued against the generalizability of the DRM task, and whether the creation of DRM false memories is comparable to the naturalistic creation of false autobiographical memories outside of the laboratory, such as memories of child abuse recovered in psychotherapy[39,40,41]. Nonetheless, several studies have found that subjects that are more susceptible to DRM false memories are also more prone to autobiographical memory distortions[42], fantastic autobiographical memories (alien abductions[43]; past lives[44]), and recovered autobiographical memories[45].

In short, the DRM task has been a useful tool to investigate the neurocognitive underpinnings of the (re)constructive nature of memory[15,16], regardless of the ongoing debate about how appropriate and relevant it is in the study of autobiographical false memories[7]. In the current report, the DRM task procedures are explained in their simplest form, with a focus on targeting memory consolidation processes (*i.e.* experimental manipulations, such as sleep and stress, occur after encoding has finished and are thus used as tools to evaluate consolidation), as this has been the focus in our laboratory. The authors refer the reader to Gallo (2013)[46] for an excellent review of the DRM task, along with the different variations on encoding and testing procedures.

Protocol

The Institutional Review Board of the University of Notre Dame approved all of the procedures, including use of human subjects, discussed here. The preparation and the administration of the DRM task materials described below were used in a published study[28], in which the effects of psychosocial stress following DRM word list encoding were assessed 24 h later.

1. Preparation of DRM Task

1. Use the word lists from Stadler, Roediger, and McDermott[47], presented in the Appendix, to select the appropriate number of word lists for the experiment. From **Tables 1** and **2**, select the word lists with the highest probability of false recall and recognition. The more word lists used in the experiment, the greater the number of false words participants will have a chance to remember.
   NOTE: **Tables 1** and **2** show the probability of false free recall and recognition memory, respectively, of the top 18 word lists used by Stadler *et al.*[47]. The Appendix presents the complete word lists. See also Gallo and Roediger[48] for additional normed word lists.
2. **Prepare the encoding task**
   1. Choose modality of presentation of word lists. See Discussion for issues regarding the selection of presentation modality.
      NOTE: Presentation modality can be either visual or auditory.
   2. If auditory presentation is chosen, digitally record all the words in each list. Use professional-grade equipment (*e.g.*, Rode NT1-A microphone), preferably an unfamiliar voice and a soundproof or sound-resistant room.
   3. Record the word lists in descending strength of association, as they are presented in the Appendix, at a rate of one word every two seconds.
   4. At the end of each list, include a reasonably long delay (*e.g.*, 12 s) of silence, followed by a 1 s tone, 2 s of silence and then the start of the next list. This helps participants parse the individual lists.
   5. Use a audio-editing software (*e.g.*, Audacity) to apply these standards.
      1. Drag and drop the audio file into the audio-editing software.
      2. Use the mouse cursor to select the portion of audio to which silence will be applied.
      3. On the top, select Edit>Remove Audio>Silence Audio.
      4. To apply the 1-s tone at the start of each list, use the copy and paste options in the audio-editing software.
      5. To save the recording, press STOP, select File>Export, and choose file format and destination of the audio file.

3. **Prepare the testing task**
   1. Choose a retention interval between encoding and testing that is appropriate for the experiment. If addressing the effects of stress on memory performance, choose at least 24 h.
   2. **For the free recall task,** have a blank piece of paper or a blank document in a word-processing application (*e.g.*, MS Word) ready.
   3. **For the recognition task,** select words to include in recognition task.
      1. Include study words (*i.e.* words presented at encoding) from positions 1, 8, and 10 from each list included in the encoding task[2]. See Appendix for complete word lists.
      2. Include all critical lure words (*i.e.* false words not presented at encoding that represent the gist of the word list) from each list included in the encoding task. See Appendix for complete word lists and their appropriate critical lure.
      3. Include the same number of additional, non-presented words (*i.e.* foil words that are unrelated to any of the studied DRM lists), from other, non-studied DRM word lists, from the same positions (1, 8, and 10) and their corresponding critical lures.
         NOTE: For example, if 15 DRM word lists are presented during encoding, for the recognition test, present 120 words: 45 study words, 15 critical lure words, 45 nonpresented list items from other non-studied DRM word lists, and 15 critical words from those nonstudied DRM word lists.

   4. Use experiment creation software (*e.g.*, E-Prime) to create self-paced presentation of the words and to achieve data collection.
      1. Use black font with a white background, and reasonable font size, depending on screen size/resolution.

2. In a standard old/new recognition test, use separate keys to assign responses; such as the 'Z' key for old and the 'M' key for new. If possible, add this legend in with the presentation of each word on the screen. Software such as E-Prime will automatically collect reaction times and key responses.

2. Administration of DRM Task

1. **Administration of encoding task**
    1. Ask subject to sit in front of device containing the recording of the word lists. Ensure subject is comfortable.
    2. Read the following instructions to the subjects: "For this cognitive task you will be listening to lists of words. At the final word of each list, there will be a 12 s break, followed by a 1 s tone, followed by 2 s of silence, and then the start of the next list. Please pay close attention to the words because you will be tested on them at the next session."
    3. Ask subject to put on headphones. To ensure participants have no distractions, turn off the computer monitor. Press play.
    4. Inform participant that this session has ended and provide them with instructions for the next (testing) session.

2. **Administration of testing task**
    1. **Free recall test**
        1. Ask subject to sit down in front of a table or desk (if using pen and paper) or in front of the computer (if using a word processing blank document).
        2. Read the following instructions to the subject: "This part of the task involves a simple memory test. Please write down all the words you can remember from the lists you heard in the last session. You have 10 min to recall all the words you can. When there are 2 min left, I will let you know. Any questions?"
        3. Answer any questions the subject may have.
        4. Start the timer and inform subject of the two-minute warning mark.
        5. Stop subject after time is up.

    2. **Recognition test in the computer**
        1. Open recognition test with the experiment creation software.
        2. Ask subject to sit in front of computer.
        3. Read the following instructions to the subject: "This is a simple recognition task. You will see a word on the screen. Use the keyboard to answer whether each word is old (that is, on one of the lists you heard/saw previously) or new. You will use the 'Z' key if you think the word is old and the 'M' key if you think the word is new. This is self-paced, but we are also measuring your reaction time, so answer as quickly but accurately as you can. Let me know you are done. Any questions? ".
        4. Answer any questions the subject may have.
        5. Start the recognition test and wait for the subject to finish.

    3. Debrief the subject and thank them for their participation in the study.

Representative Results

Using the procedure presented here, the authors have been able to reliably produce the DRM effect in two independent experiments; that is, subjects recall and recognize, with high probability, non-presented critical words that can be considered false memories for the 'gist' of the word lists.

Results for experiment 1 (see **Figures 1** and **2**) have been published elsewhere[28]. In that experiment, 67 subjects arrived at the laboratory, listened (through headphones) to 15 DRM word lists and then were submitted to a psychosocial stress task involving public speaking (Trier Social Stress Test) or a control version of the task. Subjects returned 24 h later to complete the free recall test, immediately followed by the recognition test, as described above. Of relevance to the current report, the overall proportion of words recalled and recognized was higher for critical words (false recall $M = 0.20$, false recognition $M = 0.71$) than for presented words (true recall $M = 0.09$, true recognition $M = 0.65$), $t(66) = 8.61$, $p < 0.001$, Cohen's $d = 1.22$ for recall [**Figure 1**]; $t(66) = 2.42$, $p = 0.02$, Cohen's $d = 0.29$ for recognition [**Figure 2**]). Importantly, recognition of critical words was also significantly higher than recognition for unrelated foil words ($M = 0.36$), $t(66) = 12.88$, $p < 0.001$, Cohen's $d = 1.57$.

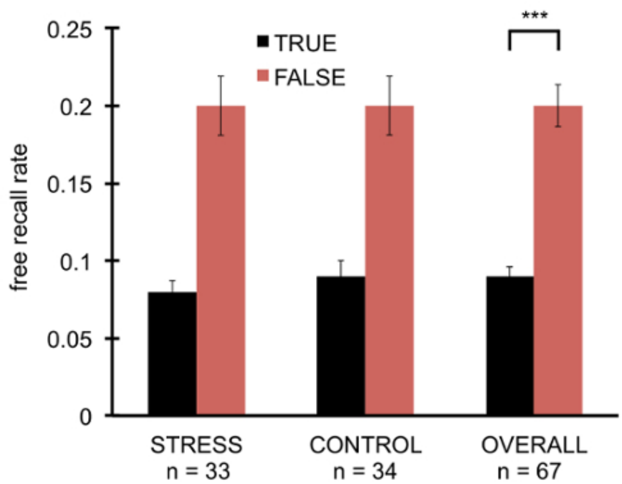

Figure 1: Recall Rates from Experiment 1 (Pardilla-Delgado *et al.*, 2016)[28]. Bars represent means and error bars represent standard error of the mean. Relevant to this report, the overall memory for false recall (last two bars) is significantly higher than memory for true recall and recognition. *** p <0.001. Please click here to view a larger version of this figure.

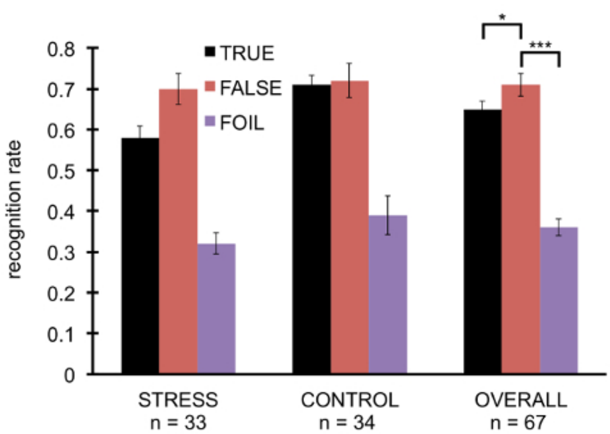

Figure 2: Recognition Rates from Experiment 1 (Pardilla-Delgado *et al.*, 2016)[28]. Bars represent means and error bars represent standard error of the mean. Relevant to this report, the overall memory for false recognition is significantly higher than memory for true and foil recognition (last three bars). * p <0.05; *** p <0.001. Please click here to view a larger version of this figure.

Similar results were obtained in experiment 2[49] (see **Figures 3** and **4**). In that study, 117 subjects encoded 16 DRM word lists either at night, before going to sleep, or during the morning, prior to a period of wakefulness. Subjects returned 24 or 48 h later to complete the free recall test followed by the recognition test. The overall proportion of words recalled and recognized was higher for critical words (false recall M = 0.20, false recognition M = 0.72) than for presented words (true recall M = 0.09, true recognition M = 0.65), $t(116) = 12.4$, $p < 0.001$, Cohen's d = 1.36 for recall [**Figure 3**]; $t(116) = 3.66$, $p < 0.001$, Cohen's d = 0.39 for recognition [**Figure 4**]). Importantly, recognition of critical words was also significantly higher than recognition for unrelated foil words (M = 0.37), $t(116) = 15.68$, $p < 0.001$, Cohen's d = 1.44.

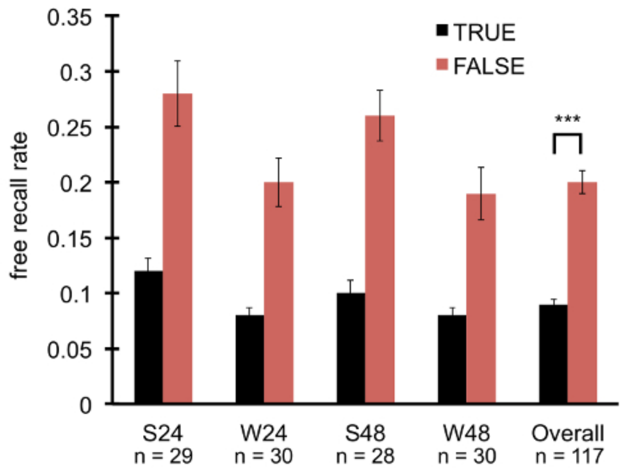

Figure 3: Recall Rates from Experiment 2 (Pardilla-Delgado et al., 2017)[49]. Bars represent means and error bars represent standard error of the mean. Groups: S24: Sleep 1st/24 h delay, W24: Wake 1st/24 h delay, S48: Sleep 1st/ 48 h delay, W48: Wake 1st/48 h delay. Relevant to this report, the overall memory for false recall (last two bars) is significantly higher than memory for true recall. *** p <0.001. Please click here to view a larger version of this figure.

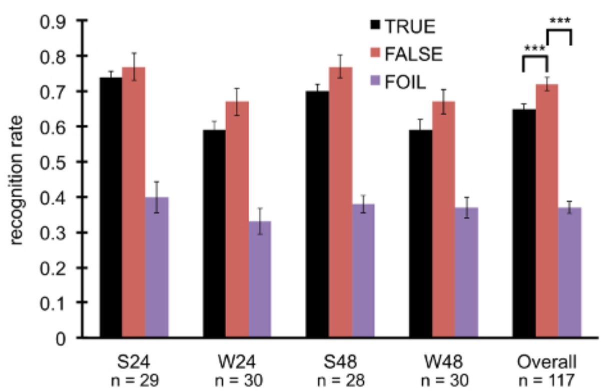

Figure 4: Recognition Rates from Experiment 2 (Pardilla-Delgado et al., 2017)[49]. Bars represent means and error bars represent standard error of the mean. Groups: S24: Sleep 1st/24 h delay, W24: Wake 1st/24 h delay, S48: Sleep 1st/ 48 h delay, W48: Wake 1st/48 h delay. Relevant to this report, the overall memory for false recognition (last three bars) is significantly higher than memory for true and foil recognition. *** p <0.001. Please click here to view a larger version of this figure.

The fact that, in these two independent studies conducted in our laboratory, false memories (critical words) were remembered proportionally more often than true memories (studied words) 24 and 48 h after encoding is consistent with early studies that showed a similar false memory persistence effect over long delays[21,22,23]. These results underscore the efficacy of the DRM task in eliciting false memories across lengthy delay intervals, at least as false memories can be broadly defined as remembered events that were not actually experienced by the subject.

Probability of false recall ranked from highest to lowest according to Stadler *et al.*, 1999	
WINDOW	65
SLEEP	61
SMELL	60
DOCTOR	60
SWEET	54
CHAIR	54
SMOKE	54
ROUGH	53
NEEDLE	52
ANGER	49
TRASH	49
SOFT	46
CITY	46
CUP	45
COLD	42
MOUNTAIN	42
SLOW	42
RIVER	51

Table 1: Probability of false recall ranked from highest to lowest according to Stadler *et al.*, 1999[47]. Stadler and colleagues[47] found that the lists associated with these critical words have the highest probability of producing a false memory in a free recall test. Presented here are the critical words only (*i.e.* the nonpresented word that is falsely remembered at retrieval testing). See the Appendix for each complete list.

Probability of false recognition ranked from highest to lowest according to Stadler *et al.*, 1999	
WINDOW	84
SMELL	84
COLD	84
ROUGH	83
CUP	82
SOFT	81
SLEEP	80
ANGER	79
SWEET	78
TRASH	78
CHAIR	74
SMOKE	73
HIGH	72
DOCTOR	71
THIEF	70
MOUNTAIN	69
SLOW	69
MUSIC	69

Table 2: Probability of false recognition ranked from highest to lowest according to Stadler *et al.*, 1999[47]. Stadler and colleagues[47] found that the lists associated with these critical lure words have the highest probability of producing a false memory in an old/new recognition test. Presented here are the critical lures only (*i.e.* the nonpresented word that is falsely remembered at retrieval testing). See the Appendix for each complete list.

Critical words (in alphabetical order) with list items (ranked by associative strength) for the top 18 lists for free recall								
ANGER	**CHAIR**	**CITY**	**COLD**	**CUP**	**DOCTOR**	**MOUNTAIN**	**NEEDLE**	**ROUGH**
mad	table	town	hot	mug	nurse	hill	thread	smooth
fear	sit	crowded	snow	saucer	sick	valley	pine	bumpy
hate	legs	state	warm	tea	lawyer	climb	eye	road
rage	seat	capital	winter	measuring	medicine	summit	sewing	tough
temper	couch	streets	ice	coaster	health	top	sharp	sandpaper
fury	desk	subway	wet	lid	hospital	molehill	point	jagged
ire	recliner	country	frigid	handle	dentist	peak	prick	ruddy
wrath	sofa	New York	chilly	coffee	physician	plain	thimble	coarse
happy	wood	village	heat	straw	ill	glacier	haystack	uneven
fight	cushion	metropolis	weather	goblet	patient	goat	thorn	riders
hatred	swivel	big	freeze	soup	office	bike	hurt	rugged
mean	stool	Chicago	air	stein	stethoscope	climber	injection	sand
calm	sitting	suburb	shiver	drink	surgeon	range	syringe	boards
emotion	rocking	county	Artic	plastic	clinic	steep	cloth	ground
enrage	bench	urban	frost	sip	cure	ski	knitting	gravel
RIVER	**SLEEP**	**SLOW**	**SMELL**	**SMOKE**	**SOFT**	**SWEET**	**TRASH**	**WINDOW**
water	bed	fast	nose	cigarette	hard	sour	garbage	door
stream	rest	lethargic	breathe	puff	light	candy	waste	glass
lake	awake	stop	sniff	blaze	furry	sugar	can	pane
Mississippi	tired	listless	aroma	billows	pillow	bitter	refuse	shade
boat	dream	snail	hear	pollution	plush	good	sewage	ledge
tide	wake	cautious	see	ashes	loud	taste	bag	sill
swim	snooze	delay	nostril	cigar	cotton	tooth	junk	house
flow	blanket	trafic	whiff	chimney	fur	nice	rubbish	open
run	doze	turtle	scent	fire	touch	honey	sweep	curtain
barge	slumber	hesitant	reek	tobacco	fluffy	soda	scraps	frame
creek	snore	speed	stench	stink	feather	chocolate	pile	view
brook	nap	quick	fragrance	pipe	downy	heart	dump	breeze
fish	peace	sluggish	perfume	lungs	kitten	cake	landfill	sash
bridge	yawn	wait	salts	flames	skin	tart	debris	screen
winding	drowsy	molasses	rose	stain	tender	pie	litter	shutter

Appendix: Critical Words (in Alphabetical Order) with List Items (Ranked by Associative Strength) for Top 18 Lists for Free Recall. Bold words at top represent the 'gist' of the list and are considered the critical words (false memories); these words are not presented at encoding.

Discussion

In this report, the authors described a highly used cognitive task that reliably produces gist-based false memories in human subjects. It is important to note that, in the current report, the DRM task was presented in one of its simplest forms, very similar to the original protocol used by Deese[1] and Roediger and McDermott[2]. The similarity with the original protocol used in the experiments described here has one particular exception: a long delay (24, 48 h) between encoding and testing, which is useful when testing the persistence of false memories over true memories[22] or following manipulations that can affect memory consolidation, such as sleep[27,49] and stress[28]. Related to this issue, in the current experiments, the recognition test was administered immediately after the free recall test, which has been found to increase recognition rates[2,18]; therefore, we caution the reader to interpret our recognition data accordingly. Additionally, although several early [2] studies, as well as the presented studies suggest that critical words (false memories) are consistently remembered better than study words (true memories), others have shown the opposite pattern, particularly for short term memory tests[17,18].

The DRM task has multiple modifications (for review, see[46]), ranging from, but not limited to: 1) changes to encoding processing, such as warnings about the effect[25], relational and associative processing instructions[50,51], priming[52], incidental encoding[53], and rapid word presentation[54]; 2) changes to the testing method, such as forced-choice tests[55], speeded recognition tests[56], and recollection vs. familiarity judgments[2]; and 3) changes to critical word features, such as using taboo words[57], long words[58], and concrete words[58].

There are several important factors researchers should consider when using the DRM paradigm. Here, we recommend using the work from Stadler *et al.* (1999)[47] in order to choose the word lists to be presented at encoding. In the study by Stadler and colleagues, subjects recalled each list immediately after listening to the words, whereas the recognition test was given after all lists had been presented and recalled. Therefore, recall and recognition rates may vary if longer retention intervals are used, as we have done in our laboratory. Our mean false recall rates were M = 0.20. Across shorter delays, like those used by Stadler *et al.*[47] mean false recall rates can be higher (*e.g.*, M = 0.51 for the top 18 lists[47]). Further, we recommend using auditory presentation, as it is the more common of the two modalities (visual or auditory). Visual presentation has also been shown to decrease the DRM effect[60,61]. Depending on the experimental question and if a more detailed assessment of memory is desired, individual confidence ratings can be added at testing, to both recall and recognition tasks. For the recognition test, "remember" and "know" judgments[62] can alternatively be used. In our studies, participants were given 10 min for the recall task to allow them to retrieve as many words as possible, because 1) 180 words were presented at encoding (15 lists; 12 words/list) and 2) there were 24 - 48 h intervals between encoding and testing, which was bound to reduce retention. Regarding statistical analysis, although in the current report we presented uncorrected recognition rates (for simplicity), the reader might consider signal detection methods to analyze the recognition test data[63] (see Seamon *et al.*[23] for a good example of signal detection methods with the DRM task). Regarding tools and materials, in the event that experiment creation software is not available, word presentation for the recognition test can also be done using slideshow creation software (*e.g.*, PowerPoint), while having subjects answer old/new on a sheet of paper.

One particularly important factor to keep in mind for future experiments is that increasing the number of semantically related words in each list boosts the false memory effect[64], *i.e.* in order to increase the probability of false recall/recognition, it is paramount that experimenters present as many words as possible (for each list) during encoding; see Appendix for the complete word lists. Similarly, using an insufficient number of word lists may also decrease the ability to observe a clear effect, especially regarding correlations (*i.e.* statistically significant correlations are more difficult to observe when the range of a variable is small, as would be the case if few DRM word lists were included in a study[27]). In contrast, this is opposite to the suggestion of, if using recognition as the testing method, not including some of the list items at encoding in order to use them as non-presented foils during recognition testing. Related to this, it is suggested to include critical lures from non-studied DRM word lists in the to-be-recognized words[18], because DRM critical lures have higher word frequencies and higher baseline false alarm rates than study (list) items[2,65]. This is one procedure that represents a high-threshold correction that addresses response bias. Another possible procedure is using signal detection methods(see Seamon et al.[23]).

The DRM is not without its limitations. Some have argued that the simple gist-based errors caused by the DRM task are related to spreading activation in semantic memory networks in the brain and may not be comparable to false autobiographical memories, such as the "recovered" memories of child abuse resulting from psychotherapy[41]. Although addressing this decade-long question is outside the scope of this report, the authors agree with Gallo in that "the appropriate questions to ask are what aspects of the DRM illusion are relevant to what aspects of autobiographical memories" (p. 834)[7]. Related to this dilemma, using the original DRM task, as described in the current report, can result in ambiguous interpretations because there are several activation/monitoring processes that govern this type of gist-based false memory formation[66]. Broadly speaking, future applications of the DRM task should continue addressing the reconstructive nature of memory, and more specifically, the transformation of single episodes into generalizable, flexible, and useful gist abstractions. Regardless of the research question, caution is always warranted when generalizing the results of studies using the DRM false memory task to other, real-world, forms of false memory, as the DRM task is a humble cognitive paradigm, yet one with great research potential.

Disclosures

The authors have nothing to disclose.

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